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THE INFLUENCE OF HABITAT STRUCTURE ON SPIDER DENSITY IN A NO-TILL SOYBEAN AGROECOSYSTEM

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ABSTRACT. The goal of this research was to investigate the relationship between habitat structure and spider density in soybean fields managed under conservation tillage practices. Previous studies suggest that spiders respond to vegetational structure, and fields which are not tilled tend to have greater vegetational structure due to higher densities of weeds. Experimental subplots with varying densities of weeds (High, Medium, and Low weed) were established in soybean plots in southwestern Ohio. By the end of the season significantly more web spiders were found in treatments with higher weed densities. Across the season more than 87% of the spiders observed were orb-web weavers and sheet-web weavers. When considered separately, both of the common types of web spiders had higher densities in areas with higher densities of weeds. However, the degree to which orb and sheet-web weavers attached their webs to weeds differed across treatments. Orb-web weavers were more likely to attach their webs to weeds than to soybean plants or ground/ground litter in Medium weed density treatments. Sheet-web weavers were more likely to use weeds as a web attachment substrate in High weed density treatments.

A variety of studies have demonstrated a relationship between the structural complexity, or vegetational diversity, of a particular area and the abundance and/or diversity of web-building spiders (Colebourne 1974; Olive 1980; Robinson 1981; Rypstra 1986; Gunnarsson 1988,1990; Döbel et al. 1990; Uetz 1991; Ward & Lubin 1993; Wise 1993; Pettersson 1996). Web spiders should be particularly sensitive to structural features of their environment because of the specific spatial requirements of web placement (Colebourne 1974; Riechert & Gillespie 1986; Uetz 1991). Indeed, experiments which changed existing features of a habitat, or added artificial substrate to which spiders could attach their webs, have demonstrated that spiders positively respond to such structural alterations (Robinson 1981; Rypstra 1983; McNett 1995).

The role spiders play in the food web and their potential as agents of biological control is becoming clearer (Riechert & Lockley 1984; Riechert & Bishop 1990; Young & Edwards 1990; Carter & Rypstra 1995). Conventional managment of agricultural fields leads to a structurally homogeneous environment which may minimize the abundance and diversity of spiders. However, in recent years, management practices designed to reduce erosion have become more popular in the United States, even though they lead to an increase in weed density and diversity (Gebhardt et al. 1985). The structural and microhabitat diversity provided by these weeds should enhance the web spider community and, in turn, may reduce the impact of pest insects. In a three year study, Rypstra & Carter (1995) found a positive correlation between spider density and weed biomass, and a negative correlation between spider density and herbivore damage in a soybean agroecosysem. Their study was purely correlative across fields and years so a more controlled investigation of the manner in which weeds may influence the spider community in a no-till agricultural system is warranted.

The goal of this study was specifically to relate weed density within no-till soybean fields to the abundance of web building spiders. Weed densities were manipulated in a replicate design and the web-spider community monitored across the season in order to test the hypothesis that the structural diversity provided by the weeds enhances spider abundance. In this way, we can begin to understand specifically how the changes in tillage practices implemented by American farmers may be impacting the other components of the biotic community that live in agroecosystems.

METHODS

Field work was conducted at Miami University's Ecology Research Center (ERC), located three miles northeast of Oxford, Butler County, Ohio USA. In 1995 we randomly selected three of twelve 60 × 70 m (0.42 ha) soybean plots, planted in an east/west direction separated by 15 m corridors of mowed grass. Soybeans were planted on 6 June and three herbicides (Roundup™ (glyphosate, N-(phosphonomethyl) glycine in the form of its isopropylamine salt; 0.96 kg active ingredient/ha), Dual 8E™ (metolachlor; 2.03 kg active ingredient/ha), and Lorox Plus™ (linuron plus chlorimuron; 0.67 kg active ingredient/ha)) were applied pre-soybean emergence on 7 June. Two herbicides (Poast Plus™ (sethoxyoim plus dash; 0.23 kg active ingredient/ha) and Cobra™ (lactofen; 0.20 kg active ingredient/ha)) were applied post-soybean emergence on 11 July and 12 July, respectively, in conjunction with a crop oil concentrate/surfactant (2.34 kg/ha with Poast Plus™ and 1.17 kg/ha with Cobra™). The plots were not tilled at any time during the season.

Nine 1.0 × 1.0 m^2 subplots were placed within each of the 0.42 ha plots by generating coordinates on a 1 m grid using a random number table. Each subplot was at least 10 m away from any other and assigned to one of three weed density treatments: High, Medium, and Low weed densities. In subplots designated as Low, all weeds were manually removed weekly to maintain low weed structure. Subplots initially designated as Medium or High treatments were reassigned at the end of the field season depending on natural weed colonization in each subplot. Subplots with weed densities between 10–16 stems/ m^2 were assigned to the Medium treatment and 18–27 stems/ m^2 to the High treatment.

Data were collected every other week over a two month period, beginning on 25 July when the soybeans were in the mid-vegetative stage and ending 16 September, when the soybeans had senesced (Teare & Hodges 1994). We combined data for the first month (two sampling dates between 25 July–23 August) and refer to it as Early season. Similarly, we combined data for the second month (two sampling dates between 23 August–16 September) and refer to it as Late season. Early and Late season each consisted of two plant and two spider census samples. A mean value for each plot and treatment was calculated for both Early and Late seasons.

Quantification of plant structure.—Weed density was measured by placing a meter stick on the ground parallel to the soybean row, touching the soybean stems. At two randomly chosen points along the length of that meter stick, another meter stick was placed on the ground perpendicular to the soybean row. The number of weed stems contacting the length of the second meter stick was recorded. Weed vertical structure was measured by dividing the subplots into four quadrats of 50 × 50 cm each. We selected two of these quadrats using pairs of random integers between one and four. At random locations within these chosen quadrats, a meter stick was positioned vertically and the number of weed leaves contacting its length was recorded. We calculated the vertical structure of the weed community by summing the number of weed leaves contacting the two meter sticks placed perpendicular to the ground. Soybean vertical structure was measured at the same two points as weed density, by holding a meter stick vertically in the soybean row and counting the number of soybean leaves in contact with the meter stick. We calculated the soybean vertical structure by summing the number of soybean leaves contacting the two meter sticks placed perpendicular to the ground. Weed and soybean height were calculated using the highest point a weed or soybean leaf touched the vertical meter stick.

Spider census.—Web spider density data were collected between 0730–0930 h when dew increased web visibility. First we searched each subplot for spiders on the vegetation and on the ground surface. Then we systematically inspected each plant starting at the base and moving upward. Each spider found was categorized according to its web type. Sheet-webs, (spun by Agelenidae, Linyphiidae), consisted of a horizontal sheet of silk sometimes bordered by a tangle of silk. Orb-webs, (spun by Tetragnathidae, Araneidae), were two-dimensional and mostly circular, with radii extending from the hub to the periphery. Any tangle or damaged webs we encountered were placed in a separate category. We also recorded the specific substrate to which each web was attached: ground/ground litter (plant debris), soybean, weeds, or some combination of the three.

RESULTS

Quantification of plant structure.—Approximately seven species of weeds invaded the no-till soybean plots in 1995 (Table 1). Weed density per m^2 and weed vertical struc-

Table 1.—Common and scientific names of the most abundant weed species invading no-till soybean fields of southwestern Ohio in 1995.

Common name	Scientific name
Giant ragweed	*Ambrosia trifida*
Common ragweed	*Ambrosia artemisifolia*
Foxtail (grass)	*Setaria* sp.
Common milkweed	*Asclepias cyriaca*
Fescue (grass)	*Festuca elatior*
Ivy	*Convolvulus sepium*
Canadian thistle	*Cirsium arvense*

ture were significantly different among the three treatments in both time periods (Table 2). Weed height, soybean vertical structure, and soybean height did not differ between the three treatments in either season (Table 2).

Spider census.—Although in the Early season weed density had no effect on the density of spiders per m^2 (Table 3), there was a significant effect of weed density on spider abundance in the Late season (Table 3). Pairwise comparisons of the late season data suggest that there were significantly more spiders in High weed subplots than in Low weed subplots where weeds were removed (Duncan's New Multiple Range Test (DNMR), $P < 0.05$). If the data are uncoupled so each subplot and treatment are included, there is a significant correlation between the number of spiders and number of weed stems counted in subplots in the Late season ($r^2 = 0.356$, $P = 0.001$).

Orb-web weavers comprised 44% of the spiders censused both in the Early and Late seasons. The dominant orb-spinner in this system was *Glenognatha foxii* (McCook 1894) (Araneae, Tetragnathidae). In the Early season, the mean number of orb-webs per m^2 was not different among treatments; however, by the Late season there was a significant treatment effect (Table 3). Pairwise comparisons suggest High weed subplots had significantly more orb-weavers when compared to Low weed subplots (DNMR, $P < 0.05$). Orb-web weavers attached their webs to different substrates in different treatments ($\chi^2 = 16.74$, $df = 4$, $P < 0.005$, Fig. 1). More orb-webs were attached to weeds in Medium weed density treatments than in High or Low weed density treatments.

Sheet-web weavers comprised 43% of the spiders censused in both the Early and Late seasons. *Meioneta micaria* (Emerton 1882) (Araneae, Linyphiidae) was the dominant

Table 2.—Summary of vegetation structure within the experimental treatments (mean ± SE). Experimental treatments included High weed density (High), Medium weed density (Medium), and Low weed density (Low).

	High	Medium	Low	ANOVA results
Weed density per m^2				
Early season	22.5 ± 1.2	11.8 ± 0.9	3.7 ± 0.1	$F = 105.7$, $df = 2$, $P < 0.05$
Late season	21.3 ± 4.5	16.0 ± 1.8	8.0 ± 0.8	$F = 5.48$, $df = 2$, $P < 0.05$
Weed vertical structure (sum leaf number)				
Early season	42.0 ± 7.5	31.7 ± 3.7	5.7 ± 5.7	$F = 10.07$, $df = 2$, $P < 0.05$
Late season	53.5 ± 2.8	33.8 ± 7.0	0	$F = 38.46$, $df = 2$, $P < 0.05$
Soy vertical structure (sum leaf number)				
Early season	24.8 ± 3.6	22.2 ± 2.8	23.9 ± 1.0	$F = 0.228$, $df = 2$, $P > 0.05$
Late season	19.8 ± 2.1	20.3 ± 2.5	21.3 ± 2.0	$F = 0.110$, $df = 2$, $P > 0.05$
Soy height (cm)				
Early season	61.0 ± 3.4	61.8 ± 4.1	60.9 ± 4.2	$F = 0.016$, $df = 2$, $P > 0.05$
Late season	85.5 ± 1.8	80.7 ± 2.2	81.5 ± 1.9	$F = 1.799$, $df = 2$, $P > 0.05$
Weed height (cm)				
Early season	47.0 ± 6.1	44.5 ± 7.8	27.0 ± 2.0	$F = 1.480$, $df = 2$, $P > 0.05$
Late season	68.4 ± 8.1	48.2 ± 8.4	66.5 ± 17.0	$F = 1.532$, $df = 2$, $P > 0.05$

Table 3.—Summary of the total number of webs, subsequently broken down into sheet webs and orb webs, within the three weed density treatments (mean ± SE).

	High	Medium	Low	ANOVA results
Total number of webs per m^2				
Early season	3.6 ± 0.5	4.7 ± 0.5	2.2 ± 0.7	$F = 3.564$, $df = 2$, $P > 0.05$
Late season	9.4 ± 0.6	7.1 ± 0.5	4.9 ± 1.3	$F = 5.914$, $df = 2$, $P < 0.05$
Number of sheet webs per m^2				
Early season	1.6 ± 0.2	2.3 ± 0.7	1.3 ± 0.3	$F = 0.994$, $df = 2$, $P > 0.05$
Late season	5.0 ± 0.2	2.6 ± 0.4	2.1 ± 0.8	$F = 7.226$, $df = 2$, $P < 0.05$
Number of orb webs per m^2				
Early season	1.6 ± 0.6	2.1 ± 0.9	0.8 ± 0.4	$F = 0.924$, $df = 2$, $P > 0.05$
Late season	4.0 ± 0.5	3.0 ± 0.4	1.5 ± 0.5	$F = 6.664$, $df = 2$, $P < 0.05$

sheet-web spinner in the fields. As was the case for orb-web spiders, we found no treatment effect on sheet-web weavers until the late season (Table 3). At that time, High weed subplots had significantly more sheet-weavers than Low weed subplots (DNMR, $P < 0.05$). Sheet-web weavers also utilized different web attachment sites as weed density changed ($\chi^2 = 14.91$, $df = 4$, $P < 0.005$, Fig. 2). Unlike orb-weavers, sheet-weavers were more likely to attach their webs to weeds in High weed subplots than in Low or Medium weed subplots.

DISCUSSION

The manipulation of weed density clearly affects the spider density in no-till soybean agroecosystems. We presume this relationship was due to differences in web support structures and/or the availability of appropriate microhabitats. Increased structural complexity has previously been correlated with spider abundance and diversity (Greenstone 1984; Rypstra 1986). Likewise, the addition of artificial web support structures has repeatedly resulted in an increase in web-spiders (Robinson 1981; Rypstra 1983; McNett 1995).

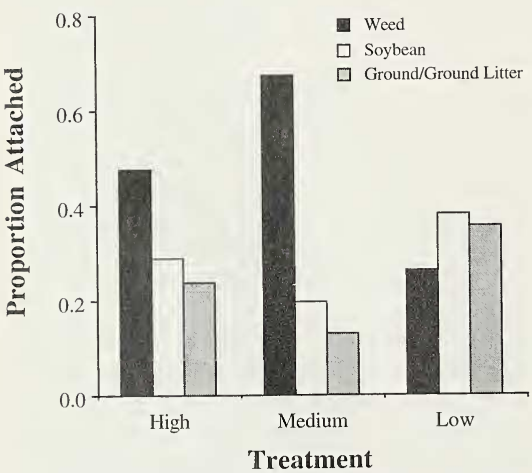

Figure 1.—The proportion of orb-webs attached to each substrate (weed, soybean, ground/ground litter) within each weed density treatment (High, Medium, and Low).

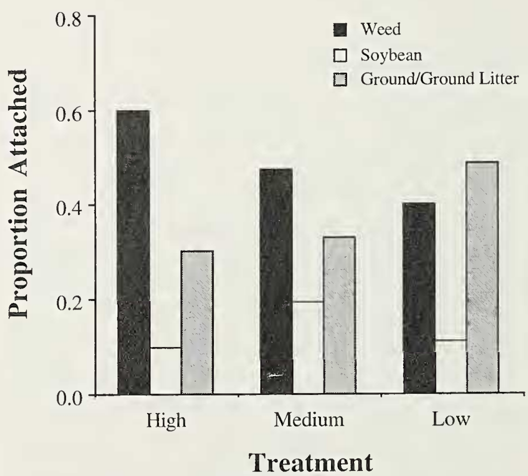

Figure 2.—The proportion of sheet-webs attached to each substrate (weed, soybean, ground/ground litter) within each weed density treatment (High, Medium, and Low).

Here we attempted to be as realistic as possible by monitoring the effects of natural plant invaders on web-spiders in an economically important habitat. These spiders rarely attached their webs to just one substrate as they would be forced to if we had used artificial constructs to alter the structural complexity available to them. Most of them used a combination of available plants, ground litter, and dirt as web substrates (Figs. 1, 2).

Difference in weed abundance not only changes the structural complexity of the environment but also ameliorates the microhabitat under the vegetation; especially near the ground surface. Most of the spiders surveyed were small (< 2 mm), and the majority of the webs were constructed on the lower third of the vegetation. Small spiders are more prone to dehydration than larger spiders due to their relatively high surface area to volume ratios (Pulz 1987). Building webs lower in the vegetation where there is increased humidity results in less direct exposure to sunlight, reducing the chance of dehydration. Also, a spider's ability to build an efficient capture web is maximized at certain thermal conditions (Barghusen et al. 1997), which may be present lower in the vegetation. Web destruction by wind is another factor affecting web site tenacity (Hodge 1987). The bases of plants provide sturdy support for web attachment and are less affected by wind.

If the high spider density in the presence of weeds was due to an increase in web supports, then one would predict that the spiders would be more apt to use weeds for web attachment in the weedier plots. In our plots, spiders tended to use the soil surface less and use weeds more as weed density increased (Figs. 1, 2). Although orb-web weavers used weeds to a high degree at Medium weed densities, they reduced their usage of this substratum in the High weed plots. It may be that orb-web weavers, who have very specific requirements for appropriate web placement, were responding more to microhabitat changes in the High weed treatments than to structural features. Once they established themselves in the plot, the regular spacing of the row of soybean plants may have offered a greater number of open spaces suitable for their planar webs. In a field study such as this, it is difficult to uncouple the relative role of structural complexity and microhabitat in producing the observed differences in web spider abundance. The differences we observed in web substrate usage in response to weed density between sheet and orb-web weavers is intriguing and deserves further investigation.

Spiders are important generalist predators in terrestrial systems and no-till soybean agroecosystems are an increasingly important terrestrial habitat in the United States (Gebhardt et al. 1983). Rypstra & Carter (1995) demonstrated that spider density was positively correlated with weed biomass across years in conventionally tilled soybean fields. Typically, a reduction in tillage leads to an increase in weeds (Gebhardt et al. 1983). In this study, we demonstrated that, within one year, weed density in no-till soybean fields influenced spider abundance. These data contribute to our understanding of how shifts in agricultural practices may affect the spider community which may have larger implications for the productivity of the agroecosystem.

In the process of censusing for spiders it was necessary to disturb the vegetation within the subplots. The greater the vegetational structure within a subplot the greater the disturbance caused by the close visual inspection of the plants and soil surface. Therefore some spiders present in the subplots were probably overlooked due to web destruction. Since disturbance is related to the amount of vegetation, sampling error should have resulted in our values of spider density being underestimates in the Medium and High treatment subplots. Therefore any effects we report as significant would only be more striking if we had been able to find every spider.

Web spider density is increased by weed density presumably due to an increase in structural complexity. The close relationship we observed between weed density and spider density helps to explain the observed relationship between weed biomass and spider density Rypstra & Carter (1995) found across three seasons. Our work offers a greater understanding of how spider communities interact with the plant communities around them. It also offers us further insight into habitat selection by spiders and gives us a greater understanding of the animal community in agroecosystems.

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